LEAP HI: Engineering Smart Solutions to Enhance Resilience and Sustainability of Built-up Environments under Changing Climate

1. Introduction

1.1. Background and Motivation: The objective of the proposed research, education, and social implementation activities examines the fundamental question of promoting sustainable floodplain and ecosystem restoration to address engineering issues and impacts due to climate change. The proposed study will focus on a region chronically impacted by anthropogenic modifications, climate change and advance knowledge about the socio-economic impact of floodplain management. The underlying goal will be to rehabilitate the effects of climate change and human interventions on the floodplain and ecosystem. The findings of the proposed research will assist floodplain managers to implement state of the art knowledge and provide a sustainable approach to regions with similar issues through the partnering effort between scientists, professionals, and stakeholders. The proposed research will also involve students and give exposure through outreach activities especially to underrepresented students, such as African American, Native American, Hispanic and female students. Under the PI's guidance, students will improve their skills for future interdisciplinary research. Additionally, we will design new courses at Southern Illinois University to train and educate students in the Civil and Environmental Engineering Program and Sociology Department.

Transferability: Deer Creek watershed and East St Louis in Cahokia Canal/Horseshoe Lake Watershed has a long history of flooding problems particularly related to urbanization, poor floodplain management, stormwater management, and changing climate. The proposed study explores flood and riparian ecosystems within the Cahokia Canal/Horseshoe Lake Watershed and Deer Creek watershed and its implications on its sustainability. Similar flooding, ecosystem, and riparian challenges are common and increasing in communities located along creeks and rivers in the US. Although this study is specifically applied to the East St. Louis area included in Cahokia Canal/Horseshoe Lake Watershed and Deer Creek watershed and similar studies can be developed to better understand urban flooding issues in other regions with similar problems. As such, long-term goal of this research is to investigate the transferability perspective to other communities.

"The consequences of anthropogenic activities and climate change are inevitable while improved mitigation can minimize safety impacts on society and the environment while increasing the quality of life."

Based on the IPCC 2018 report, the direct risks of global climate change are expected to have growing effects in urban areas. Urban growth is accompanied by landscape modification and an increase in impervious areas, thereby increasing urban flooding vulnerability (Meyer et al., 2013, Revi et al., 2014). The core element of urban infrastructure is asphalt and concrete which contribute to the surge of gray infrastructures (Wilbanks and Fernandez, 2014). Urban development thus often results in increased surface runoff due to deteriorated pervious surfaces. Moreover, the risks of urban flooding are exacerbated due to destructive runoff flow velocity along with extreme peak flows (Li and Wang, 2009). Some of the flooding events over the past 25 years in the central U.S. severely disrupted societal functions and led to fatalities and large financial losses (Xiao et al. 2013). In the past three decades, flooding has resulted in losses of ***$8.2bn*** each year on average according to the National Weather Service, Flood Loss Data of 2015. The implications of urban flooding are not limited to just human and economic losses. It poses a greater health related threat as sewer overflow and entry of contaminated water can lead to outbreaks of diseases (Chen et al., 2015). Furthermore, the projected increase in the magnitude and frequency of precipitation events attributed to climate change pose significant effects on rivers and their riparian zones (Garssen et al., 2015). One driving factor of climate change impacts is direct or indirect human intervention in the natural processes. Anthropogenic activities affect the overall climatic balance leading to changes in precipitation patterns. Therefore, it is of paramount significance that restoration activities be carried out by state and local administrations considering the projected impacts of climate change.

Flooding is the most costly and common natural disturbance affecting the United States. Every 9 out of 10 presidential disaster declarations are flood related. Misguided efforts in the early- to mid-20th Century concentrated on mitigating flood losses through building various flood control infrastructure that modified river morphology and degraded riverine habitat over time. This had led to people and assets becoming increasingly vulnerable to flood-related disasters (UNISDR, 2013). Increasing losses are expected in many inter-dependent domains such as health, security, and economic and societal well-being. Pervasive flooding, as exemplified in the project area, is rooted in a changing climate, urbanization, and improper flood-control infrastructure. With such varied and complex roots, public institutions, scientists and stakeholders must work together to achieve an effective model of sustainable flood risk management practices that restores natural floodplains. Additionally, flooding problems will be alleviated if concerned authorities thoroughly integrate effective mitigation mechanisms into local ordinances, codes and practices. These mechanisms can be focused on bettering the functioning of floodplain ecosystems in a basin. Floodplains are the integral intermediate habitat between river and terrestrial ecosystems (Mitsch et al. 2008). A well-functioning floodplain enables a healthy water balance, provides sediment control and promotes sustainability, thus benefiting society and the environment. Natural floodplains are largely undeveloped areas that primarily serve as habitats to indigenous species. However, natural floodplains can also drain excessive amounts of storm water during floods, thus preventing serious harm to humans. Conversely, anthropogenic activities pose severe stress on natural floodplains resulting in an imbalance and transformation of the natural functioning of the floodplains. Anthropogenic activities often change the storage and conveyance of water, nutrients, and sediments affecting the ecosystem and community health. To overcome this, water and ecosystem managers are prompted to restore a channel configuration to promote the natural functioning of the rivers. Primarily, ecosystem restoration is intended to improve the natural recharge and storage of a river reach by increasing the detention and retention time, which will reduce the flood peak downstream. In an urban setting, upsizing the pipes are not a good alternative, so trails and detention basins are effective to reduce flooding. These will also provide multiuse recreation facilities in urban areas where open spaces are limited and have high pollution. Carefully designed modifications to channels and ecosystem restoration will accommodate large discharges. This, in conjunction with flood mapping, forecasting, and warning systems, provides a strong long-term mitigation option.

In addition, Wright (2011) showed that changes in levee protection were closely related to the racial composition of neighborhoods in New Orleans. In fact, in the mostly white and affluent areas, in contrast to the black and working-class areas, there was 5.5 feet of increased levee protection. Bullard and Wright (2009) pointed out that black victims were more than twice as likely as white storm victims to still be living in temporary housing three years after Hurricane Katrina. They also showed that neighborhoods that were in the range of 75–100% black at the time of the 2000 U.S. Census were flooded. Together, these racial disparities point to inequities in infrastructure across class and race. Physical vulnerability to hazard events, such as flooding or storm surge, is potentially compounded by inadequate funding, investment, and maintenance of infrastructure, especially for social groups who have been segregated or marginalized into risky areas or housing. This dynamic illustrates the intersection of social and physical vulnerability to disaster.

Homelessness is one of the most significant issues affecting human health, well-being, and ecosystem services in the United States. On any night, more than 500,000 people experience homelessness in the U.S., and that number is now rising after several years of decline. In fact, the number of unsheltered homeless individuals increased by 9% between 2016 and 2017. The problem is particularly evident in East St. Louis, which has the 5th largest increase in the homeless population in the country in 2016-2017 despite having only the 5th highest population overall as of 2019. The racial disparity in experiencing homelessness is evident in East St. Louis (Figure 1). The percentage of unsheltered homeless that are black in East St. Louis is 76%, which represents the quite highest unsheltered rate in the nation. Even more concerning is the fact that East St. Louis has the 4th highest population in 1950 with the highest black people (HUD 2017; Help Hope Home 2017). East St. Louis is also one of the most dangerous cities in Illinois.

Beyond the socioeconomic plight, there are also environmental consequences associated with the unsheltered homeless due to improper waste disposal, poor sanitation practices, and inadequate facilities

(Figure 1). Considering that the time between measurable rainfall events is sometimes as long as three months, the fecal contamination could potentially accumulate and lead to a tremendous pathogen spike to the drinking water infrastructure during storm events. With this increased risk of waterborne disease, there is also potential for the wastewater infrastructure to be inappropriately implicated, thereby threatening the moral and cognitive legitimacy of potable reuse (Harris-Lovett et al. 2015). Moving forward, it is important to not only address specific symptoms (e.g., water pollution, waterborne disease) but also major human (e.g., poverty) and ecosystem (e.g., water scarcity) stressors and modifying factors (e.g., long-term drought) exacerbating the issue of homelessness. An improved characterization of the homeless population and its potential impacts on public and environmental health is only the first step to enacting change. Despite the ongoing economic recovery, homelessness is a serious problem that will continue to plague communities throughout the U.S. Therefore, policymakers and other stakeholders must become more familiar with the dynamics of homelessness and its potential coupling with critical resilient interdependent infrastructure systems and processes. The proposed research employs a transdisciplinary approach to characterize the interdependence and resilience of (1) flood control, (2) stream restoration, and (3) climate-resilient water infrastructure systems in an urban ecosystem, specifically in the context of potable reuse.

1.2 Problem Statement: Deer Creek watershed in Missouri and East St. Louis in Illinois experiences chronic flooding. Several flooding events over the past century in the historically vulnerable area indicate a need for a sustainable approach to mitigate future flooding. Deer Creek watershed has experienced 26 damaging flooding events since 1957. In September 2008, flash flood on interior streams that had a significant impact in St Louis County that damages 302 commercial properties. Floodplain fill and other impairments introduced during the conversion of undisturbed land into commercial use over the last century has reduced channel conveyance and floodplain storage and has impeded infiltration during stream overflow and heavy rainfall events. The frequent inundation of properties and the roadway itself has been a concerning problem for city officials and residents, often raising questions regarding public safety and property damages. Additionally, the degraded floodplain has decreased the availability of natural greenspace to residents. Due to public health and safety concerns, some parts of the area surrounding the creek have been declared as **'blighted'**. Recurrent flooding has led the area to be less desirable, resulting in real estate and sales tax decline. Building and site improvements have become depressed, businesses have moved out, and properties remain on the market for extended periods. ***Without the flood mitigation efforts, this decline is expected to continue.***

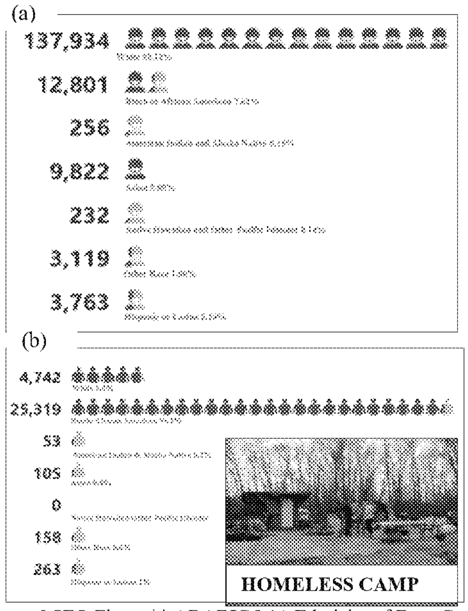

Figure [SEQ Figure * ARABIC] (a) Ethnicity of Deer Creek Watershed (b) Ethnicity and Homeless camp in East St. Louis

The Deer Creek Watershed is a sub-watershed to the River Des Peres Watershed. Sections of Black Creek, River des Peres and Deer Creek are listed on the Missouri Section 303 (D) list of impaired waters for E. coli, chlorides, and Clean Water Act for low Dissolved Oxygen (DO). Prairie du Pont Creek and Harding Ditch impairments listed in 2018 include dissolved oxygen, and past impairment include total phosphorus, total suspended sediment and fecal coliform, all of which can contribute to harmful algal blooms. Schoenberger Creek's impairments include bottom deposits, Total Phosphorus, sludge, turbidity, Ammonia, Manganese, and low dissolved oxygen, all of which contribute to human and ecological health problems. Frank Holten Lake's main impairment is Polychlorinated Biphenyls (PCBs), highly toxic chemicals that can affect the liver, cause birth defects, and effect development health in young children. The watershed is along the receiving end of water from **37 square miles** of the fully developed urban watershed from **22 different towns**. A study conducted by Washington University in St. Louis revealed that some of the unhealthiest water quality parameters in the Deer Creek watershed are in or near the proposed project area. The lowest average DO level (7.1 mg/L) of the 20 sample sites was located approximately 0.7 miles downstream from the Deer Creek project area. Floodplain restoration will not only decrease flood levels but will mitigate poor water quality. In addition, in 2009 the Illinois state ***EPA declared that the Harding Ditch, which drains the American Bottom, contained hazardous levels of fecal coliform.*** It has become, effectively, an open sewer. The most recent Centreville flood occurred on January 11, 2020. The degraded creek add to the growing concerns over the safety of the residents and its impact on public health. The adverse effect of the flooding problem around the creek directly impacts many of the businesses along Brentwood city, who are forced to sandbag and evacuate during heavy rainfall events. Boat rescues have been necessary during dangerous events, including record events in 2008. ***Severe flooding escalates quickly and unexpectedly often reaching to three feet of water in the first 10 hours of a heavy rain event. Business owners along Manchester Road at times are left with no other option than to flee their businesses in order to protect their lives.*** Continuous flooding has led to stagnant economic growth of the area. In addition, flooding has turned the creek area into a neglected space with limited public recreation potential and has threatened the limited aquatic habitat. Since 1981, local and federal entities have repeatedly investigated the scope of the flooding problem, ecosystem degradation, and mitigation options. In 1988, the St. Louis Metropolitan Sewer District generated updated hydrology for Deer Creek through their Storm Water System Master Improvement Plan. The City has since hired professionals to complete a hydraulic analysis of the area using updated hydrology and to develop projects to mitigate the recurring flooding issues. The professionals developed four projects for the consideration of the City and its Board of Aldermen, who ultimately approved an alternative in 2017 as the preferred plan to address the flooding problem along Deer Creek. The approved alternative, which this grant application seeks to aid in implementing the stream bank stabilization and restoration. The mitigation features are expected to reduce construction and maintenance costs while still achieving the restoration of Deer Creek and river in East St Louis into a viable ecological habitat that safely conveys the 100-year flood. Thus, ***the community will promote flood resilience by transforming a previously developed urban space prone to flooding to a restored recreational green space.*** These efforts will improve community resiliency in a changing climate. The incorporation of real time flood alert technology will also improve resiliency by alerting stakeholders to prepare for potentially destructive events.

Figure [SEQ Figure * ARABIC] Erosion is evident along Deer Creek near Litzsinger Road in Ladue.

Human-induced impairment of urban runoff leads to deterioration of recreational and drinking water quality and reductions in human well-being and ecosystem services. Yard waste decaying in creeks and rivers decomposes in a process that removes oxygen from the water. Fish and other aquatic life can't survive in water with low oxygen. As yard waste decomposes, plant nutrients such as nitrogen and phosphorus are also released. These nutrients promote the excessive growth of algae in the water. As the water becomes polluted, it does not support aquatic life and becomes a health hazard. Leaves and woody debris naturally accumulate in streams and creeks, however, when you collect and dispose of yard waste along creek banks, the added yard waste covers the ground and keeps out the natural vegetation that helps to stabilize the bank. This practice leads to increased erosion and sedimentation that clouds creek water and destroys habitat for aquatic life (Figure 2). Improper disposal of yard waste increases the accumulation of debris which in turn can lead to blockages that inhibit proper drainage. Although it is common for some homeowners to dispose of yard waste along creek banks, it is not good practice. *Drainage is the first thing to secure for a completion of any Engineering Project.*

2. Project Description

2.1. Integrative Research: The project will focus on integrative research that addresses fundamental technological and social science dimensions and evaluate pilot solutions together with communities. The project will promote a sustainable approach to maximize flood resilience and ecosystem restoration within the study area using state-of-the-art technologies by providing an ample platform for communal involvement. The research will incorporate the multidisciplinary perspectives of scientific areas jointly addressing the technological and social science dimensions of communities. The key goal of this research proposal is based on fulfilling the technological and social science dimensions that are highly relevant to advance the watershed management goals (stream bank restoration, Green Infrastructures (GI), water quality monitoring, resilience to flooding), maintain the ecological processes and support stakeholders. The technological-cum-social aspect based goals of this work are: (1) Evaluate the impacts on future water quantity as a result of climate variability and anthropogenic modifications of the floodplain; (2) To assess the floodplain management system based on implications to future climate change and community; (3) To restore the riparian ecosystem in an urban setting; (4) To analyze the ways to develop the flood-prone area into a community-friendly space (5) Generate a framework for sustainable floodplain management; and (6) Based on the created framework, communicate the new knowledge to stakeholders (agencies and users like city residents) for data accumulation and decision-making processes.

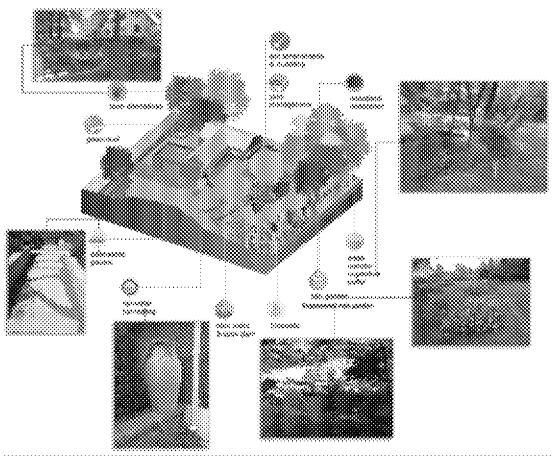

Figure [SEQ Figure * ARABIC] Rainscaping-Beautification to

The significance of the research is installing rainscaping including rain gardens, permeable pavements, lawn alternatives, vegetative buffers as stormwater management efforts for beautification to engineered systems of GI networks (Figure 3), which are designed to mimic the hydrology of natural landscapes that enhance water infrastructures resilience. This project employs a systematic approach that could be practicable to implement in Cahokia Canal/Horseshoe Lake Watershed, East St. Louis to local conditions. Three test case study in Cahokia Canal/Horseshoe Lake Watershed will also be conducted, where similar engineering issue is prevalent but has racial disparity, to improve the ongoing stormwater and water quality issues and establish the basis for replication in a wide range of communities. Detention basins are very effective alternatives in urban areas where large spaces are limited. These detention basins can be constructed in Parks near the flood issue river to prevent flash floods. These smart solutions are essential to alleviate flood within the limited urban area. By necessarily improving our capability to predict early floods events dissemination, this project aid to restore and improve urban infrastructure, installation of BMPs, and monitor water quality.

We propose an integrated watershed hydrological, high-resolution 2D hydraulic and riparian habitat modeling to study flood mitigation (quantification of inundation extent during different flood events such as 100-year) and riparian vegetation recruitment in the proposed restoration area. The hydraulic model will include the quantification of inundation extent during different flood events, including the 100-year recurrence interval. The research connects and analyzes the relationship between human impacts (change in land use), flood hazards, ecosystems, and social benefits. The hydrological model of the watershed quantifies/helps to develop matrices of how watershed management (e.g., land use change and increase in permeable areas) impacts runoff in urban streams. Hydraulic modeling of urban streams and the floodplain will be used to delineate high-risk areas for flooding and estimate the flood inundation extent for different flood events, which can be used to design flood mitigation approaches. The model can be used to assess habitat conditions (e.g., riparian) for different flow scenarios. Existing riparian vegetation models can be adapted (i.e., Benjankar et al., 2014; Benjankar et al., 2011) to predict habitat for native riparian vegetation as a result of proposed floodplain and channel restoration. The riparian vegetation model will be used to update and improve current vegetation plans if modeling results indicate different recruitment strategies will have higher survival rates. Moreover, the proposed project will be aligned with the mitigation/restoration implementation plan.

2.1.1 Research Questions: The study will contribute to the body of knowledge for water and ecosystem management integrated with communities by pushing the knowledge boundaries on (1) How resilient is the community and ecosystem within the existing floodplain; and what are the prospects of increasing community resilience within the chronically impacted area? (2) What will be the future flood scenarios under changing climate and urbanization? (3) What improvements are needed to improve community resilience and to restore the ecosystem? (4) What are the impacts of the current project on the community and ecosystem?

2.1.2 Research Plan:

Objective 1: Create a collaborative environment among residents, local government, and project planners:

Task 1.1: Survey residents about their perceptions of the community, how connected they are in the community, and what they would like to see happen with the study area: At the beginning of the project, we will survey 1,000 residents in the nearby study area and other adjoining communities. The questions will address residents' levels of community sentiment, indicators of social capital, and perceptions of the study area, including what they would like to see as the outcome. An example survey question measuring community sentiment is a matrix style question with the lead in: ***Please rate your community as a place to live by indicating whether you agree or disagree with the following statements:*** *1) Being a resident is like living with a group of close friends. 2) If you do not look out for yourself, no one else area will. 3) Most everyone is allowed to contribute to local governmental affairs if they want to. 4) When something needs to get done, the whole community usually gets behind it. 5) Community clubs and organizations are interested in what is best for all residents.*

Policy-relevant survey research will be conducted. During the survey collection process, age, gender, race, and partisanship will also be reflected in a region's demographics. Any imbalances in the survey sample will be quickly detected and corrected in the field, rather than relying solely on post-survey techniques for big corrections. Social science coupling with engineering smart solutions is essential to address racial inequity and urbanization issues contributing to deteriorate water infrastructures and quality that facilitates the communication with the residents to maintain water quality and infrastructures in an efficient way.

Task 1.2: Conduct focus groups among residents to gain a clearer understanding of general barriers, challenges, and goals for the study area: One of the questions in the survey will be if the respondent would like to participate in a focus group to better understand barriers and challenges they see in the community and what goals they would like to see for the study area. We will then hold two to three focus groups comprised of volunteer residents, with a maximum of 10 residents in each focus group. We will take measures to ensure that each focus group is diverse concerning age, gender, and race and ethnicity. During the focus groups, a facilitator will ask residents open-ended questions about the community and study area, with an emphasis on discussing some of the design plans for the study area.

Objective 2: Hydrologic and hydraulic modeling for the study area:

Task 2.1: Development of hydrologic model: A current hydrologic analysis will be carried out using the 'Runoff' module of XPSWMM version 2019, SP1. The modeling work will utilize the hydrologic inputs and parameters developed for the Metropolitan Saint Louis Sewer District (MSD) Deer Creek Watershed Storm Water System Master Improvement Plan (1998) (SSMIP) as well as in East St. Louis as shown in Figure 3 and 4. This model will be run to develop flows specifically for this study, using design storms that reflect the most up-to-date published and peer-reviewed rainfall intensity-frequency atlas values available. Overland flow will be generated for each hydrologic unit in the watershed using the XP-SWMM RUNOFF block based on properties of the ground slope, width, Manning's overland roughness coefficient, and initial abstractions. The hydrologic model will be delineated into sub-basins within the 37 square mile Deer Creek Watershed and Cahokia Canal/Horseshoe Lake Watershed. Peak flows will be routed through the open channel stream network in SWMM and the open channel system using the 'Hydraulic' module. Flow hydrographs for the project will be extracted from the XPSWMM model at the design points from both the Runoff and Hydraulic module. The number of critical points for BMPs installation and detention basins will also be assessed and will be included in the model. The potential locations that will reduce the runoff and improve the water quality will be determined as a preliminary assessment to reduce the flood risk. The sample BMPs and detention basins are shown in Figures 5 and 6.

Task 2.2: Development of hydraulic model: A hydraulic analysis will be conducted to evaluate the proposed project improvements along the stream to help reduce flooding. The U.S. Army Corps of Engineers HEC-RAS version 5.0.3 will be used to perform hydraulic calculations. To estimate the peak stages along the channel, downstream boundary conditions of normal depth will be established, and the unsteady flow simulations will be performed using the relevant flow hydrographs. The hydraulic model will include the Deer Creek channel starting at the mouth of River Des Peres at the downstream end to 3.53 miles upstream. 1.06 miles of Black Creek is included starting from its confluence with Deer Creek. 0.38 miles of Hampton Branch will also be included from its confluence with Black Creek because of its proximity to the proposed improvements. Similarly, the channel along the Schoenberger and Harding Ditch will also be modelled because of its flood impact to the Centerville and East St Louis. A networked model that includes junction nodes at the confluences of the

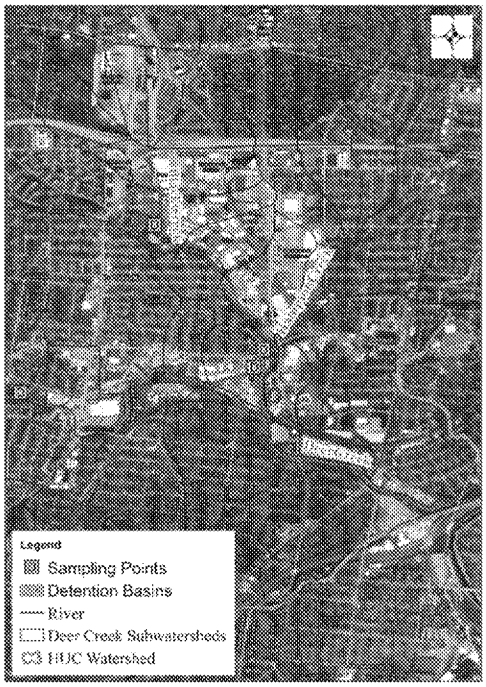

Figure 5 Sampling sites & Detention Basin along Deer Creek

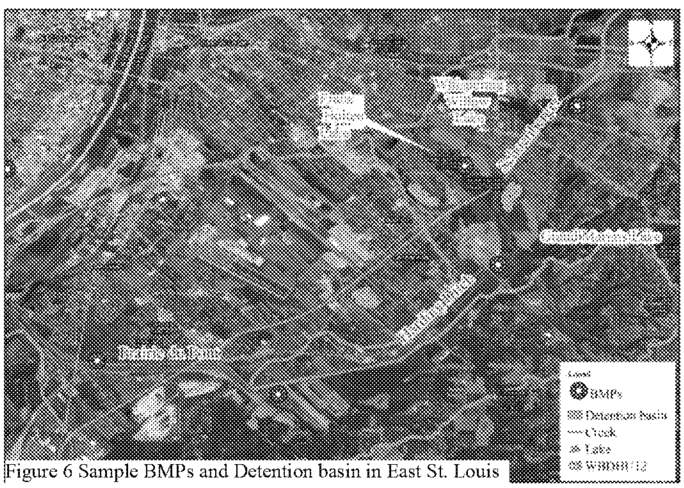

Figure 6 Sample BMPs and Detention basin in East St. Louis

creeks will be created because of the need for unsteady flow simulation. For the HEC-RAS hydraulic model, Deer Creek will be divided into two reaches at its confluence with Black Creek. Additionally, Black Creek will be divided into two reaches at its confluence with Hampton Branch.

Water quality section

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Objective 3: Development of ecosystem/ecohydraulic modeling: An existing riparian vegetation model will be utilized to predict riparian habitat development as a results of current hydrologic conditions, proposed channel and floodplain restoration, and implementing different climate change scenarios [ADDIN EN.CITE <EndNote><Cite><Author>Benjankar</Author><Year>2014</Year><RecNum>1212</RecNum><DisplayText>(Benjankar et al., 2014)</DisplayText><record><rec-number>1212</rec-number><foreign-keys><key app="EN" db-id="v5pv5vpwgtaxt1eppdz5aw2izxff29p2dd9e" timestamp="0">1212</key></foreign-keys><ref-type name="Journal Article">17</ref-type><contributors><authors><author>Rohan Benjankar</author><author>Michael Burke</author><author>Elowyn Yager</author><author>Daniele Tonina</author><author>Gregory Egger</author><author>Stewart B. Rood</author><author>Norm Merz</author></authors></contributors><titles><title>Development of a spatially-distributed hydroecological model to simulate cottonwood seedling recruitment along rivers</title><secondary-title>Journal of Environmental Management</secondary-title></titles><periodical><full-title>Journal of environmental management</full-title></periodical><pages> 277-288</pages><volume>145</volume><dates><year>2014</year></dates><urls></urls></record></Cite></EndNote>]. First, the model will utilize hydraulic parameters simulated from the hydrologic (Task 2.1) and hydraulic (Task 2.2) model and field surveyed riparian vegetation at reference site to calibrate the model. Later the calibrated model will be used to predict riparian habitat development for different flow scenarios representing proposed channel and floodplain restoration and implementing climate change. If current hydraulic conditions are not suitable for natural recruitment of riparian vegetation, we will use the model to predict areas for plantation and integrate the planting plans with the proposed mitigation design.

Task 3.1 Development of a vegetation model: The HEC-RAS model developed in Task 2.2 will be upgraded to a two-dimensional (2D) hydraulic model. 2D models can simulate water surface elevation in channels, and calculate water depths, velocities and inundation patterns for rivers and floodplains and can effectively model features like narrow bridges and discrete features. HEC-RAS 2D hydraulic software, developed by the US Army Corps of Engineers (USACE), is a numerical model of channel and floodplain which simulates channel and floodplain hydraulics [ADDIN EN.CITE <EndNote><Cite ExcludeAuth="1"><Author>US Army Corps of Engineers (USACE)</Author><Year>2016</Year><RecNum>1578</RecNum><Prefix>USACE`, </Prefix><DisplayText>(USACE, 2016)</DisplayText><record><rec-number>1578</rec-number><foreign-keys><key app="EN" db-id="v5pv5vpwgtaxt1eppdz5aw2izxff29p2dd9e" timestamp="1565368029">1578</key></foreign-keys><ref-type name="Report">27</ref-type><contributors><authors><author> US Army Corps of Engineers (USACE),</author></authors></contributors><titles><title>HEC-RAS River Analysis System: User's manual, Version 5.0</title></titles><pages>962</pages><dates><year>2016</year></dates><pub-location>Davis, CA</pub-location><publisher> US Army Corps of Engineers</publisher><urls></urls></record></Cite></EndNote>]. It can simulate both steady and unsteady flows for different boundary conditions (discharge and water surface elevations). For this project, SIUC will use 2D HEC-RAS, hereafter "HEC-RAS2D" software to develop numerical hydraulic model and to predict flow hydraulics along the study reach. SIUE will develop a 2D hydraulic model to simulate channel and floodplain hydraulics for the 21.9 acres of proposed riparian restoration area. A set of three related models will be developed, which represent current condition (Scenario 1), after floodplain and channel restoration (Scenario 2) and implementing climate change scenarios (Scenario 3).

Publicly available existing channel and floodplain elevation data for St. Louis County, MO based on LiDAR survey ([HYPERLINK "http://msdis.missouri.edu/data/lidar/"]) will be used to develop river bathymetry for the current condition model. For scenario 2 (after floodplain and channel restoration) and 3 (implementing climate change scenarios), modification will be carried out in existing DEM at the areas where channel and floodplains were modified. Daily discharges measured at USGS 07010082 Black Creek near Brentwood, MO and USGS 07010075 Deer Creek at Ladue, MO and East St Louis in IL to perform frequency analysis and estimate different recurrent interval (RI) floods e.g., 100- and 500-year RI floods will be made. Furthermore, the daily streamflow to predict riparian vegetation development for current condition will be used. An estimation of daily flow based on watershed hydrological model for climate change scenarios will be made (Scenario 3). Survey of flow velocity and water surface elevation (WSE) for different flow conditions in the study area will be carried out. Further, Acoustic Doppler Velocity meter (ADV) for velocity measurement at multiple points and water surface elevation for different discharges for calibration and validation of the hydraulic model will be used while WSE will be surveyed using total station or Differential GPS (DGPS). The output will be calibrated and validated 2D hydraulic model for all three scenarios. Furthermore, outputs will be flood inundation extent, spatially distributed water depth, velocity, and shear stress for different RI floods (e.g., 100 and 500-year RI floods), future flood inundation extent implementing different climate change scenarios.

Task 3.2 Evaluation of vegetation model: Based on floodplain physical variables including seed dispersal period, shear stress, mortality coefficient (a function of water surface recession rate), and elevation of topography reference to the mean water level in the channel, riparian vegetation model predicts fully favorable, partially favorable, low favorable and not favorable areas for successful riparian vegetation recruitment, using rule-based Fuzzy approach [ADDIN EN.CITE ADDIN EN.CITE.DATA]. Equal weights will be assigned to each parameter and classified into good (G), fair (F) and poor (P) as in Benjankar et al. [ADDIN EN.CITE <EndNote><Cite ExcludeAuth="1"><Author>Benjankar</Author><Year>2014</Year><RecNum>1212</RecNum><DisplayText>(2014)</DisplayText><record><rec-number>1212</rec-number><foreign-keys><key app="EN" db-id="v5pv5vpwgtaxt1eppdz5aw2izxff29p2dd9e" timestamp="0">1212</key></foreign-keys><ref-type name="Journal Article">17</ref-type><contributors><authors><author>Rohan Benjankar</author><author>Michael Burke</author><author>Elowyn Yager</author><author>Daniele Tonina</author><author>Gregory Egger</author><author>Stewart B. Rood</author><author>Norm Merz</author></authors></contributors><titles><title>Development of a spatially-distributed hydroecological model to simulate cottonwood seedling recruitment along rivers</title><secondary-title>Journal of Environmental Management</secondary-title></titles><periodical><full-title>Journal of environmental management</full-title></periodical><pages> 277-288</pages><volume>145</volume><dates><year>2014</year></dates><urls></urls></record></Cite></EndNote>] based on to threshold values. We will develop three set of vegetation models, which represent the current condition (Scenario 1), after floodplain and channel restoration (Scenario 2) and implementing climate change (Scenario 3). The riparian vegetation model will be focused on the 21.9 acres of proposed riparian restoration area.

This task requires field verification of model-simulated riparian vegetation maps. The first step will be to select the reach based on a preliminary field visit and aerial photographs of the study site. The area will be selected based on observed riparian vegetation recruitment within the past 10 years by visual judgment. The field survey will be performed during the spring season to capture the seedlings that were established in the previous year. Finally, the field surveyed riparian vegetation maps will be digitized into polygons using ArcGIS. The output from the model is Geographic Information system (GIS) compatible predicted riparian vegetation recruitment maps for the specific year with four different attributes i.e., fully favorable, partially favorable, low favorable and not favorable current condition (Scenario 1), after floodplain and channel restoration (Scenario 2) and implementing climate change scenarios (Scenario 3). This information will be used to quantify change in riparian vegetation for channel and floodplain restoration scenarios.

Task 3.3: Analysis of flood management and ecosystem development: Based on inundation extent maps for different scenarios, we will analyze channel and floodplain restoration effectiveness and flood hazard for future climate change implemented flows. This information will be helpful to develop future flood management strategies. Riparian vegetation model simulated maps will be analyzed to assess the improvement in riparian habitat as a result of a channel and floodplain restoration. If channel and floodplain restoration and modified hydrologic conditions do not support natural riparian vegetation recruitment, we will predict the areas for plantation. Furthermore, the riparian vegetation model will be useful to study impacts of future climate change on riparian ecosystems.

Objective 4: Evaluate the effect of changing climate on proposed improvements:

Task 4.1: Hydrologic and hydraulic evaluation of Deer Creek system based on changing climate:
The main objective of this task will be to evaluate the impact of changing precipitation patterns as evident through climate models within the study region. The proposed floodplain through the Deer Creek will be evaluated considering the climate change by coupling the climate data with the hydrologic model of the Deer Creek system. First, the 6-hour 100-year storm depths will be calculated with the climate model driven datasets of North American Regional Climate Change Assessment Program (NARCCAP). NARCCAP model data sets are available for the time period of 1970-2000 for historic precipitation and 2040-2070 for future precipitation. These data are gridded climate model data of 50 km spatial resolution. The L-moment based Generalized Extreme Value method will be used with the regionalization for the calculation of 6-hour 100-year depth. The North American Regional Reanalysis (NARR) data is an extensive work of the National Centers for Environmental Prediction (NCEP) towards the major improvement upon earlier NCEP/NCAR Global Reanalysis (Kalnay et al, 1996, Kistler et al, 2001, Mesinger et al 2004). Reanalyses use observation and model output to produce a long-term systematic description of the climate system, and output data are considered as gridded estimation of historic observation (Kennedy et al, 2011, Kalnay et al, 1996). The 32km resolution of NARR, is more refined than NARCCAP data resolution. NARR data are available from 1979 to 2015, but same 3-hourly temporal resolution. Since the NARCCAP data do not have historic datasets after 2000, this work only considers NARR data from 1979-2000. NARR data will be used for the screening and NARCCAP for the historic design depths. Delta change factor, an alternative of complex downscaling for gridded data will be used for the calculation of climate change derived future design depths. Plugging the calculated design depths into the hydrological model (Task- 1.1) of the watersheds will be used to evaluate the future runoff through the Deer Creek. Further, the flow quantity obtained from the hydrologic model and calibrated HEC-RAS 2D model (Task- 2.1) will be used to develop a future floodplain map based on climate change. This assessment will result in making the design and management of the Deer Creek flood mitigation more resilient to climate change spurred floods.

Task 4.2 Construction of necessary infrastructure to alleviate flooding based on the findings of the research: As a part of the Deer Creek watershed management plan initiative, the research work will also drive its focus on delivering the construction of relevant infrastructure within the Deer Creek study area based on the findings of the proposed research. A planned landscape improvement for the flood mitigation project will be proposed after the completion of initial floodplain modeling. Improvements will include installation & monitoring of rain gardens, BMPs at least 5-years period, stormwater harvesting, stream bank restoration, modification of channel locations using buffer plantings at locations where construction debris and accumulated trash are present. The rainscaping cost-share program by Deer Creek Watershed Alliance will also collaborate in this projectect. Each landowner with property located in one of these Program Focus Areas (Denny, Monsanto-Sunswept, and Pebble Creek sub-watersheds, Rock Hill and Shady Grove sub-watersheds, Hampton-Claytonia and Lower Deer Creek sub-watersheds) will be eligible to receive a rebate of 75% of approved and documented costs up to a maximum of $4,500 for project design, implementation, and/or maintenance costs incurred for *Rainscaping Cost-Share funded feature(s).* Landowners including residential, institutional, and commercial are also eligible to participate. The sample plan is shown in Figure 7. The Deer Creek Trail is proposed as a new concrete trail system located on the flood bench of the flood mitigation modified Deer Creek Channel. The flood bench will be well-rehabilitated using turf seeding along with storm sewer outfall removal or stabilization. All improvements, when built in conjunction with each other, will serve to mitigate flooding in the project area by providing areas for storage of floodwaters in the restored floodplain bench areas and within the overflow storage ponds and will be resilient to changes in climate patterns.

Task 2.3 GIS framework Development: This task will be focused to develop a GIS-framework for modeling and mapping of flooding, water quality, and ecosystem model outputs in two urban watersheds for present and future analysis. The flood modelling structure will be distributed into four modules (i) delineate watershed; (ii) runoff estimation; (iii) flood inundation extent and mapping; and (iv) calibration and validation. Watershed will be delineated by constructing stream networks and drained into inlet or a low elevation point. Consequently, the flood inundation will be mapped for a given precipitation event. In this framework, runoff hydrograph at the pour point will be generated. In the case of a channel inlet, the runoff hydrograph will be linked with the discharge hydrograph and flooding characteristics will be determined. The flood depth throughout the modelled watershed will be mapped as a flood extent map. Finally, the calibration and validation of a flood model will be performed by comparing the model output with observed data. The flood depth, extent, and velocity for present and future scenarios will be extracted in GIS shapefiles (vector) or raster dataset. Similarly, riparian vegetation maps, flood plain restoration maps before and after implementing climate change scenarios will also be stored in a database. All the hydrologic, hydraulic, and ecosystem model outputs will be handed over to the City in a GIS database which can be used to update the inventory for the future development. In addition, the dataset obtained from Task 3 and 4 will also be stored in a separate GIS database for future use. This will be useful to develop a comprehensive database to exchange adequate and common information regarding hydrology, flood plain restoration, water quality to inter-agency, or among different municipalities within Deer Creek Watershed and Cahokia Canal/Horseshoe Lake Watershed.

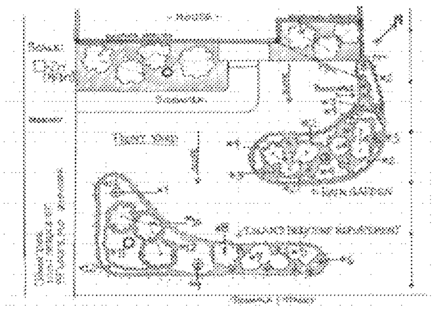

Figure 7 Sample Plan of rainscaping

2.2. Engineering Leadership Plan: The proposed grant will focus on developing a strong framework for better preparing communities during natural disasters in collaboration with multiple agencies such as Metropolitan Sewer District (MSD), 21 Municipalities in Deer Creek and 3 in East St. Louis, Deer Creek Watershed Alliance, Missouri Department of Transportation, East-West Gateway Councils of Government, Community Builders of Network of Metro St. Louis, and SIUC & SIUE scholars. The integrated decision support system from intra-municipality coordination will help the agencies to recognize the needs and have a shared vision is the utmost goal in this project. The proposed improvements to revitalize a struggling community corridor. The aim of revitalization will be carried out by improving roadway, by greatly expanding community open space and pedestrian access with a greenway, and by addressing pervasive flooding that has damaged the project area 26 times since 1957. The greenway and flood mitigation will be addressed, the proposed research activity will involve the synergistic integration of intelligent technologies with the goal to improve the social, economic, and environmental well-being. Small scale engineering systems are good but it becomes complex and uncertain when climate change becomes a factor that changes large scale engineering structures.

For the holistic improvement of the community space, residents will be extensively involved in all stages of project planning beginning with initial stakeholder and public meetings. As a part of the project initiation, various city representatives and project planners will present at the public Board of Alderman meetings and open houses and will address community members' questions, comments, and concerns. **Residents will be extensively involved in all stages of project planning beginning with initial stakeholder and public meetings.** Likewise, this research focuses on identifying and defining the challenges that nearby communities and residents regularly face. To support a community engaged strategic plan, we propose to organize an advisory council that will include residents, community leaders, government officials, project planners, and university researchers. The tasks of the council include meeting to discuss general barriers, challenges and available resources for the study area and identifying goals, aims, and resources designated for implementation and co-evaluation of the strategic plan. As a part of the project initiation, various city representatives and project planners will present in virtual meetings and small groups to minimize the risks posed by flood and climate. Likewise, this research focuses on identifying and defining the challenges that nearby communities and residents regularly face. To support a community engaged strategic plan, we propose to create an advisory council that will include residents, community leaders, government officials, project planners, and university researchers. The tasks of the council include meeting to discuss general barriers, challenges and available resources for the study area and identifying goals, aims, and resources designated for implementation and co-evaluation of the strategic plan. Some of the civic partners will be but not limited to Deer Creek Watershed Alliance, Great Rivers Greenway, Missouri Department of Transportation, and Metropolitan Sewer District. Some of the activities and events for civic engagement during the planning phase will be **open house meetings** (The Municipalities will conduct multiple open houses to discuss the benefits of the proposed pilot project and taking into account the restriction posed by flood events and climate extremes, these open houses may need to be held virtually), **social networking event** (at least one social networking event during the planning process), **special events** (information about the pilot project will be available at all special events hosted by the city), **city's website** (information about the pilot project will be kept on a dedicated website of for community feedback), **social media** (planning process and open-house related information, research updates and trail pictures will be posted on Facebook, Twitter, Instagram, and **Nextdoor** - a social networking service for neighborhoods), and the **city newsletter**. A schematic of a communication plan is shown in Figure 8.

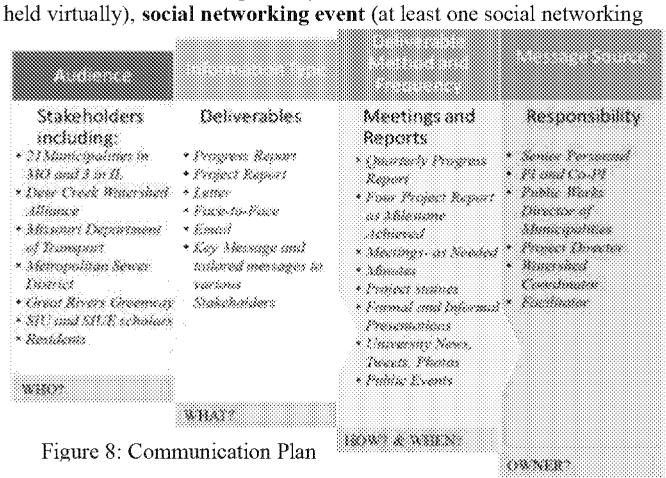

Figure 8: Communication Plan

2.3. Evaluation Plan: The goals associated with this research task are well planned and meticulously defined to judge the success of the project in terms of its applicability and implementation. The following goals are defined to serve the purpose of measuring the success of the research work.

2.3.1 Efficient operation & maintenance (O&M): The research will provide a basis to handle the operations and maintenance plans for the Deer Creek Flood Mitigation Project to offer continual flood protection benefits, continued recreational opportunities, and ecosystem maintenance for the community and to ensure the long-term success of the project. The general recommendations based on the relevant outcomes of the research with regards to the future infrastructure and as well as the climate change impacts will be to inspect and when necessary, debris removal, reinforce stream bank protection and outlet control stability on an annual basis, or after heavy rain events. The management will administer regular landscape maintenance, which will include continual invasive species management. It will also include, weeding, mulching, dead leaves removals, check pH/soil fertility if plants show signs of nutrient deficiency, fertilization, watering and the timing will vary as weekly, monthly or annually. The City will take over the O&M after completion of the proposed project. The resign of the detention basins will be implemented by the City as per the Preliminary talks with them.

2.3.2 Flood reduction: The installation of the detention basins and BMPs in the project area will be key to monitoring progress of the flood mitigation work. In particular, the research team will carry out the extensive hydrologic and hydraulic modeling that will show the expected positive changes in the 100-year floodplain as a result of the proposed improvements and identified historic peak flood levels for multiple large, damaging storm events. Monitoring of flood extents in the project area during high intensity storms (and comparing against similar modeled historic flood levels for similar peak flow rates) will be a critical component of determining the project's progress. Additionally, hydrologic and hydrological modeling has shown that the floodplain will be affected by these mitigatory changes. Extent of flooding, which shows current flood extent in blue and 100-year proposed floodplain in red is expected after completion of the project. There are multiple BMPs throughout this larger area that will also be similarly monitored and analyzed to understand any spatial extents of hydrological and hydraulic benefits. Effectiveness of the flood control practices is measurable by flow rate and flood depth comparisons, reductions in street closures, reduction in flood response related staff hours and city expenses for flood events, and necessary rescue efforts (currently, boat rescues are a regular occurrence during severe flood events).

2.3.3 Public safety: Deer Creek suffers from severe flash flooding. During a recent flood in the project area in July of 2019, the nearest USGS-monitored flood stage increased 13 feet in under 5 hours. A flood BMPs in the project area will allow city personnel and the public to identify the quality, view stream response to storms, and view in real time any resiliency effects as a result of mitigation and resiliency efforts. An automated and geographically focused flood alert system would be able to reach Deer Creek watershed's participating residents with focused information through a citizen notification system. If implemented successfully, this would give floodplain residents time to protect property or evacuate as needed and warn others to avoid the park and commercial area. The City will manage and monitor the BMPs and notification system with the primary objective of upholding public safety. Figure 6 and 7 shows the rendered images of the creek which is achievable with regards to public safety after project completion.

Figure 6: Rendered image of trail in Deer Creek after project completion

Figure 7: Rendered image of park in Deer Creek after project completion

2.3.4 Safety of businesses: A key metric in assessing the success of the project should be concerned in the smooth running of the businesses along the Deer Creek and high crime rated area East St Louis. The business activities around the creek area are often in danger due to flash floods with potential of significant losses to the business owners. Along with the economic losses, the business owners are often in physical danger during the flooding events. The restoration activities in Deer Creek and East St Louis area are expected to lessen the impact of such occurrences providing a safe and sound environment for carrying out the businesses. The restored floodplain has been designed to contain significant flood events.

The feeling of safety shown by the business owners around the Creek can be a testament to the success of the project.

2.4. Scope and Scale: The flood mitigation project is an overarching initiative, which includes three projects to invigorate Corridor along the Deer creek and East St Louis. The projects include (i) flood mitigation in a location regularly experiencing severe repetitive property damages and personal rescues, (ii) road, pedestrian and public transport improvements, and (iii) park and trail building that completes a major regional trail connection. The study area is a formerly commercialized and blighted area located in a community that currently does not have a large-scale open space with trails, ecosystem connections, and event space capabilities. This unique project and location achieve the goals for each of the three areas listed in one geographically central location. The benefits of the flood mitigation, and more largely, are cross-disciplinary. As such, awarded funds would provide an opportunity to explore and publicize the outcomes of these initiatives in a creative and exploratory way. It would also serve as a case study for other communities with similar flooding issues. This grant will provide an opportunity to quantify and share ecological, safety, economic and social benefits that Deer Creek watershed and Cahokia Canal/Horseshoe Lake Watershed will stimulate but would otherwise go unfunded.

We propose an interdisciplinary approach to increase community resilience by reducing flooding events and restoring the ecosystem through the use of available technological advances with the partnering effort among scientists, professionals, and stakeholders. With this project the PIs intend to i) mitigate flooding issues and improve community resilience in a chronically hit area, ii) restore the floodplain and local ecosystem services, iii) evaluate future flooding events under changing climate, and (iv) understand the impact of proposed improvements on a community's natural and social capitals. The project will also involve a sustainable approach of best management practices to enhance the hydrologic efficiency of the study region along with the improvement of ecosystem services (e.g. healthy river systems and riparian buffer zones). We provide several ways to increase awareness among residents, stakeholders and practitioners about the state-of-the-art technologies involved for tracking and mitigating the flooding events. In addition, residents will be included throughout the process as they will be the direct beneficiaries of the project. ***The proposed project will directly benefit the residents within the study area, Deer Creek in Missouri and East St. Louis in Illinois. Additionally, the project will benefit 2 million people in the 1,200 square mile Great Rivers Greenway service district in St. Louis City, St Louis County and St. Charles County in Missouri.*** A major aspect of the project is community engagement with community stakeholders occupying an integral position in the research. Investigators and community stakeholders will work closely to develop, pilot, and evaluate creative approaches to accomplish the goals of the proposed research with the primary intent of benefiting Deer Creek Watershed and the surrounding Greater St. Louis community. Through this project, we will introduce new ways to incorporate communication technologies, state-of-the-art water resources science and ecological knowledge with the main intent to engage interdisciplinary representatives through education, research and implementation opportunities. In addition, interdisciplinary courses will be developed to motivate future professionals to promote sustainable and safe practices for flood and ecosystem management. Moreover, professionals will be recruited to participate in workshops and seminars aimed at developing new insights and strategies to minimize the flood hazard and enhance ecosystem services. As the technical lead for installing the BMPs, will provide the required technical support to achieve this objective. The coordination required among multiple agencies for installation and monitoring of the BMPs is required for solving Engineering problems that will help to develop a comprehensive plan to manage, promote and execute the flood resilience plan.

2.5 Intellectual Merit: The research components of this interdisciplinary approach will focus on analyzing the flooding and ecosystem issues that are interlinked with the climate and impacts due to human interventions in the form of urbanization. Understanding the impacts of floodplain improvements on society will increase the resources of similar works in the future. Intellectually, we attempt to explain (i) how developed flood zones impact residents (ii) how residents perceive flood zone restoration and identify any barriers to ecological restoration, and (iii) how flood zone restoration impacts a community's natural and social capitals. To answer these questions, a team of engineers, city officials, social and environmental scientists will (i) survey nearby residents to find out how urban flooding affects them and how they would like to see the flood zone transformed (ii) hold focus groups to learn about any local challenges residents may have including trust in local government, access to outdoor recreation and natural landscapes, and opportunities to meet people and socialize, and (iii) survey residents after the flood restoration project is complete to monitor its effects on local residents. Thus, this project will study ecosystem restoration techniques to mitigate flooding, create a natural landscape for recreational uses, increase community connectivity, and seek to increase social capital and community sentiment among residents. The project will deal with the multidisciplinary approach to various complex problems and engage different entities such as community members, researchers, professionals and stakeholders. This study will also explore the technical knowledge and computing advances along with its societal benefits for developing the internet-based flood alert system. Many natural-restoration focused engineering studies rely heavily on modeling alone, but this project is valuable because it is rooted in an accessible field site with full cooperation of the municipal owner. A balance of field data and numerical modeling will enable better calibration and validation of future modeling and design efforts. In turn, this will make the case for ecological restoration for flood mitigation more convincing and its implementation more likely to be shared.

2.6 Broader Impact: The proposed project is multidimensional in scope and unique in how it fits into the comprehensive vision of watershed plan. Specified objectives, which can be thought of as co-benefits, have direct ecological, social and economic impacts that extend far past the traditional benefits of flood prevention. Quantifying the merits of these nature-based solutions requires analyzing project outcomes with a holistic lens. Ecological services will be improved through the removal of pollution and contaminants in the air, water and soil, and by the expansion of natural habitat for endemic flora and fauna. Socioeconomic services will be improved through averted damage costs and increased property values. Flood mitigation in this area has large safety benefits, with a significant reduction in personal rescues, property damages, and state highway closures.

The project will mitigate chronic flooding along Deer Creek in Missouri and Centerville and East St. Louis, Cahokia Canal/Horseshoe Lake Watershed. The project will achieve this through reducing impervious surface area and floodplain restoration. Floodplain habitat and the main channel of the creek will be revegetated and restored, and the streambanks will be widened to more stably and safely convey floodwaters. The proposed project will address stream restoration and bank stabilization through debris removal, landscaping, erosion and sediment control, and monitoring equipment. The successful completion of this project will facilitate flood relief, habitat restoration, community well-being, and utilize advanced flood warning technologies to ensure public safety. Further, the outputs from the models, more specifically the project outputs will be handed over to the City for open access public use in the form of GIS database. These objectives will be achieved through increased coordination between scientists, professionals, community members and students. The proposed research is designed to involve students of different levels (K-12, undergraduate and graduate). Under the PI's guidance, students will improve their skills for any interdisciplinary research in the future. PIs will also improve existing education and research activities whilst increasing the participation of underrepresented students. Apart from research, graduate and undergraduate students of SIUC and SIUE will also assist in community engagement and engineering tasks to achieve professional experiences through summer internships.

3. Educational Component

3.1. Background: PIs plan to mentor and support students of all backgrounds to pursue advanced degrees and to contribute to research projects in the fields of water resources, climate, sustainability, environmental resources and management. PIs will engage in uplifting existing education and research activities whilst increasing the participation of underrepresented students. PIs are passionate in improving educational outcomes for traditionally underrepresented groups. For example, PIs have developed programs like STEAM summer camps for girls, Saluki day, and Saluki Water Workshops (Fig. 8), which encourages young students to explore careers in STEAM disciplines. Co-PI Crowe is involved in an NSF S-STEM grant that provides annual stipends for students to be involved in a three-year scholar program.

When selecting students for the program, emphasis was placed on selecting female and racial minority applicants.

3.2. Students involvement: High school students will be taught about human impacts, flooding hazard, and ecosystem balance. Activities will include a one-day field visit and a monthly one-hour class during the course of a semester. High school students will learn the role of STEAM disciplines in flood hazard management and ecosystem restoration, along with the social benefits. Likewise, undergraduate students will be involved during the summer to assist with data collection with respect to the research questions. Undergraduate students will be selected on a competitive basis for a summer field trip to analyze the cottonwood recruitment and to prepare GIS based vegetation maps. Apart from research, graduate and undergraduate students of SIU will also assist in community engagement and engineering tasks to achieve professional experiences. **Graduate and undergraduate students at SIUC and SIUE will be involved in summer internships arranged.**

3.3. Development of new course modules: In order to expand the knowledge and scope of the interdisciplinary education, PI Kalra will design a course entitled **urban runoff quality & control** and will cover topics of water and environmental facilities, water economy analysis, and optimization algorithm. PI Kalra has developed a new junior level **Introduction to Sustainability** course, which has been taught since fall 2018. Another graduate level course entitled as **Environmental and Water Systems** will be developed covering the topics of water and environmental facilities, water economy analysis, optimization algorithm with linear and dynamic programming along with SD modelling. The findings from the proposed research will be added as case studies to the sustainability course and will help in realizing the underlying relationship between society, environment and sustainability. Co-PI Crowe regularly teaches courses on Environment and Society and Community Development. Undergraduates in these courses during the time of data collection will assist in the focus groups. Research findings will be included as case studies on topics of community sentiment, natural capital, social capital, and community engagement. Virtual meetings with stakeholder and students will also be conducted.

Figure 8: Presentations made under different STEAM

3.4 Expected outcomes of educational component:

1. Exposure to Native American, Hispanic and Women in outreach and research activities.
2. Broad and diversified training on components of water supply and demand, sustainable water management, water and environmental resources, geography, climate, land use and provide knowledge about several water resources software.
3. Encourage undergraduates in research and motivate them to further their knowledge boundary.
4. Broad exposure to high schools' students and motivating them for pursuing engineering and science disciplines.

4. Prior NSF Support: PI- Crowe: Award S-STEM 1564954 $3,271,703; Period: 08-2016 – 07/2021; Title: Collaborative Research: Upper Delta Region Biodiversity Scholarship. Summary of Results: Intellectual Merit: The overall objective is to recruit, retain, and train students, particularly students from traditionally underrepresented groups, in specimen collections so that they graduate and are ready for graduate school or the workplace. While the scholarship program is only in its second year, preliminary results show that scholarship participants participate in more scholarly activities, interact more with their professors, and are more engaged in the profession than a similar group of non-scholars in the major. Broader Impacts: Publications: Students have presented their own work at conferences and to each other at annual summer institutes. Crowe presented early results at the 2018 Rural Sociological Society. Publications are forthcoming.